



King's Research Portal

DOI:

[10.21037/jtd.2017.10.11](https://doi.org/10.21037/jtd.2017.10.11)

Document Version

Peer reviewed version

[Link to publication record in King's Research Portal](#)

Citation for published version (APA):

Meurgey, J-H., Brown, R., Woroszy-Chrusciel, A., & Steier, J. (2018). Peri-operative treatment of sleep-disordered breathing and outcomes in bariatric patients. *Journal of Thoracic Disease*, 10(Suppl 1), S144-S152. <https://doi.org/10.21037/jtd.2017.10.11>

Citing this paper

Please note that where the full-text provided on King's Research Portal is the Author Accepted Manuscript or Post-Print version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version for pagination, volume/issue, and date of publication details. And where the final published version is provided on the Research Portal, if citing you are again advised to check the publisher's website for any subsequent corrections.

General rights

Copyright and moral rights for the publications made accessible in the Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognize and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the Research Portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the Research Portal

Take down policy

If you believe that this document breaches copyright please contact librarypure@kcl.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

Peri-operative treatment of sleep-disordered breathing
and outcomes in bariatric patients

Jacques-Henri Meurgey¹, Richard Brown R², Asia Woroszyl-Chrusciel², Joerg Steier^{1,2}

¹King's College London, Faculty of Life Sciences and Medicine, London, UK;

²Lane Fox Respiratory Unit and Sleep Disorders Centre, Guy's & St Thomas' NHS Foundation Trust, London, UK

Contributions: (I) Conception and design: JH Meurgey, J Steier; (II) Administrative support: J Steier; (III) Provision of study materials or patients: J Steier, R Brown, A Woroszyl-Chrusciel; (IV) Collection and assembly of data: JH Meurgey, R Brown, Woroszyl-Chrusciel; (V) Data analysis and interpretation: JH Meurgey, J Steier; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Joerg Steier. Lane Fox Unit, St Thomas' Hospital, Westminster Bridge, SE1 7EH, London, UK.

Tel: +44 (0)20 7188 3434; Email: Joerg.steier@kcl.ac.uk

Abstract

Background: Obstructive sleep apnoea (OSA) is increasingly common in bariatric patients undergoing sedation during elective surgery. However, it has not been established how significant a contributor it is to peri-operative respiratory complications and mortality. We sought to pre-operatively identify OSA in bariatric patients and record peri-operative complications during and after bariatric surgery.

Methods: Data were collected and analysed from June 2014 to March 2017 for 410 bariatric surgery patients referred to the sleep laboratory for pre-operative screening and treatment of OSA. The STOP-Bang questionnaire, Epworth Sleepiness Scale (ESS) and nocturnal pulse oximetry were recorded and treatment was allocated with continuous positive airway pressure (CPAP). Peri-operative complications and mortality were the primary outcome measures for patients receiving CPAP treatment for OSA, with patients who did not require CPAP used as control. The mean follow-up time for all patients was 433 days and 732 days for the patients who had undergone bariatric surgery. The two groups were compared with Chi square test and unpaired two-tailed *t*-test.

Results: OSA was present in any form in 70% of the screened patients. 40% of patients involved in the study received CPAP treatment. Patients receiving CPAP treatment [49.5 (11.3) years old, 61% female, 50.3 (8.5) kg/m²] were older, had a lower percentage of females and had a higher BMI than those not receiving CPAP [44.9 (12.0), 81% female, 46.6 (7.7)]. No significant differences were observed between patients on CPAP and those not on CPAP, there was no significant difference in hospital stay or rate of respiratory

complications. Out of 53 patients who had undergone bariatric surgery at the cut-off date, only 1 had suffered a respiratory complication.

Conclusion: Bariatric patients who are screened pre-operatively for OSA and treated according to guidelines have no increased risk of respiratory complications compared to patients without OSA.

Introduction

The rate of obesity in the UK is one of the highest in the world (1). As of 2013, 24% of men and 25% of women in the UK are classified as obese, with 3% classified as type III obese (previously known as “morbid obesity” with a body mass index (BMI) above 40 kg/m²) (2). Obesity is linked to several respiratory conditions such as pneumonia, asthma, pulmonary embolism and obstructive sleep apnoea (OSA) (3). However, despite the increasing prevalence of obesity, up to 90% of OSA remains undiagnosed (4): 4% of middle-aged men and 2% of middle-aged women in the UK suffer from sleep apnoea (5), but severe OSA occurs in 10-20% of patients with a BMI above 35 kg/m² (6). OSA and obesity are significant contributors to cardiovascular and metabolic morbidity and mortality, associated with diabetes mellitus, ischaemic heart disease, hypertension and depression (5, 6).

In OSA, transient hypoxias induced by upper airway occlusion in sleep activate the sympathetic nervous system, increase intra-thoracic pressure swings and cause arousal from sleep (5). Heart rate increases and sleep is fragmented, the sleep quality decreases (7), causing excessive daytime sleepiness, as well as impaired cognitive function, eventually leading to an impaired quality of life (5). OSA is diagnosed by experts with the help of a sleep study (polysomnography) in conjunction with a subjective increase in daytime sleepiness, assessed with the aid of an Epworth Sleepiness Scale (ESS) questionnaire (5).

Continuous positive airway pressure (CPAP) is currently the best available treatment for moderate to severe OSA, effective to avoid upper airway collapse, inflate the chest and diminish work for breathing and neural respiratory drive (5, 8). In the context of surgery and anaesthetics, obesity and OSA are associated with a greater incidence in complications both peri- and post-operatively, leading to longer in-hospital stays and putting additional strain on healthcare providers (9). Obesity itself is not necessarily linked to increased risk of pulmonary complications pre- or post-operatively, even in the morbidly obese (10), however, in conjunction with OSA this is different (11). Patients with OSA are more than twice as likely to develop post-operative desaturations, cardiac complications, adult respiratory distress syndrome (ARDS), respiratory failure, aspiration pneumonia and other problems that require admission to intensive care (9, 11). Frequent and extended desaturations also predispose patients towards opioid-induced respiratory depression due to hypoxaemia and hypercapnia (6). However, the risk of these complications is potentially reduced if OSA is identified pre-operatively and treated with CPAP (4, 6, 9, 11).

We hypothesize that long-term and peri-operative complication rates are low in bariatric patients who are screened for OSA and, if required, treated accordingly. For this purpose, we identified peri- and post-operative mortality with long-term follow up, as well as complication rate and length of hospital stay in all screened bariatric patients and compared the occurrence of complications between patients with moderate-severe OSA with those who had mild OSA or no sleep-disordered breathing.

Patients and Methods

Retrospective data of patients referred to the Lane Fox Unit (respiratory high dependency unit, St. Thomas' Hospital, London, UK) and the Sleep Disorders Centre (Guy's Hospital, London, UK) for assessment of sleep-disordered breathing in conjunction with bariatric surgery were analysed. The study was registered as a service review and approved by the local clinical governance board (registration number: GSTT-2017-6952). Cases were included between 12 June 2014 and 9 March 2017.

Variables recorded included age (years), gender (male and female), height (m), weight at time of sleep study (kg), BMI (kg/m^2), neck circumference, waist circumference, comorbidities, medication, surgery date, surgery type, intra-operative complications, post-operative complications, length of post-operative hospital stay (days), ward vs ITU stay, post-operative weight at last follow up (kg), post-operative BMI at last follow up (kg/m^2), weight loss over the follow up period (kg/year); it was recorded whether patients were prescribed CPAP, the respective CPAP pressure (in cmH_2O), annual CPAP compliance (% of nights used), average nightly CPAP use (in hours), Epworth Sleepiness Scale (ESS, points) and Hospital Anxiety and Depression Scale (HADS, points), as well as the results of the nocturnal pulse oximetry data.

Questionnaires

Patients scheduled to undergo bariatric surgery at Guy's and St. Thomas' NHS Foundation Trust, London, UK were screened pre-operatively with the STOP-BANG questionnaire.

STOP-BANG is an acronym for snoring (significantly loud), tired (excessive daytime sleepiness), observed apnoea (others seeing the patient choking during sleep), [blood] pressure (current or treated hypertension), BMI ($>35 \text{ kg/m}^2$), age (>50 years), neck circumference ($>40\text{cm}$) and gender (male). Each parameter is graded '0' (for "no" answers) and '1' (for "yes" answers) (12). A score >4 represented a risk of OSA and indicated referral to the Sleep Disorders Centre for more extensive investigation.

The Epworth Sleepiness scale was recorded; it asks patients to rate the probability of falling asleep during eight activities of daily living on a scale of "0" to "3", with higher scores (>10) indicating daytime sleepiness (13).

The HADS is a scoring tool to assess patient's levels of anxiety and depression. There are 14 statements to score from "0" to "3", seven about anxiety and seven about depression. The questions deliberately avoid asking about sleep because changes in sleep may be symptoms of these disorders (14). This scale can be used in conjunction with the ESS (10). A score $<9/21$ on either questionnaire or a total score $<18/42$ points is deemed normal.

Nocturnal Pulse Oximetry

Patients recorded two nights of pulse oximetry at home using a Pulsox 300i (Konica Minolta sensing Inc, Hachioji, Tokyo, Japan). The data recorded and calculated included:

- Mean pulse rate (min^{-1})
- Number of pulse rises >6 beats per minute [“pulse rises”] (h^{-1})
- Mean peripheral capillary oxygen saturation (SpO_2 , %)
- Nadir peripheral capillary oxygen saturation (SpO_2 , %)
- 4% and 3% oxygen desaturation index (ODI; h^{-1})
- Time spent with $\text{SpO}_2 < 90\%$ (% of total time recorded)

The results were further assessed by an expert sleep technician and scored by a consultant.

OSA was defined by the number of desaturations a patient experienced per hour of sleep; the 4% ODI. A 4% ODI < 5 events/hour was considered normal; 5-15 events/hour was mild, 15-30 events events/hour was moderate and > 30 events/hour was considered severe OSA (9). Possible coexisting obesity hypoventilation syndrome (OHS) was indicated by prolonged periods ($> 10\%$ of the recorded time) of hypoxia ($\text{SpO}_2 < 90\%$) during sleep. Patients were assigned a value from 1-5 for the severity of their OSA:

- “1” – if no OSA present,
- “2” – if mild OSA present,
- “3” – if moderate OSA present,
- “4” – if severe OSA present,
- “5” – if patients had OSA, potentially combined with OHS

Recommended treatments were assigned a value from 1-5:

- “1” – no further action necessary
- “2” – recommendation of a mandibular advancement device if symptomatic
- “3” – recommended extubation onto CPAP
- “4” – peri-operative CPAP
- “5” – referral for inpatient assessment to investigate the potential presence of OHS

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, IBM, Chicago, IL/USA) version 24.0. Categorical variables are summarised using percentages. A Shapiro-Wilk with Lilliefors Significance correction test was used to determine whether continuous variables were normally or non-normally distributed. Normally-distributed continuous variables are cited as “mean (standard deviation)” and compared using an unpaired t-test. Non-normally distributed continuous variables are cited as “median [interquartile range; IQR]” and compared using a Mann-Whitney test. Categorical variables were compared with a Chi-square test. A Pearson correlation test was used to compare independent and dependent variables; a Spearman correlation test was used to compare non-normally distributed data. A p value of <0.05 was deemed statistically significant.

Results

Demographics

410 patients awaiting bariatric surgery were studied, the majority were female, middle aged and obese [74% female (302:108), age 46.9 (11.9) years, weight 134.5 (27.5) kg, BMI 48.1 (8.2) kg/m², waist circumference of 136.7 (16.7) cm, neck circumference 43.6 (4.5) cm]. Four patients were excluded from the analysis because they had insufficient or unobtainable sleep results. The average of patients was not excessively sleepy, but were considerably susceptible to depression and/or anxiety [ESS 8.0 (5.0) points, total HADS 17.7 (7.3) points]. Most patients (85.9%, n = 352) had a BMI >40 kg/m², 12.4% (n = 51) had a BMI between 35-40 kg/m² and 1.7% (n = 7) patients had a BMI between 30-35; 34.2% (n = 140) of the patients were “super obese” with a BMI ≥50 kg/m²; the highest BMI was 88.9 kg/m².

Sleep disordered breathing

Nocturnal pulse oximetry data revealed mild-moderate OSA for the total cohort [4% ODI of 15.4 (17.3) h⁻¹, 3% ODI of 20.1 (19.6) h⁻¹, mean SpO₂ of 94.1 (3.6) %, a nadir SpO₂ of 75.9 (10.0) %, mean pulse rise index of 34.0 (18.6) h⁻¹, and a time below SpO₂ of 90% of 8.0 (14.2) % of the sleep study]]. 285 out of 410 patients (70%) had at least some degree of OSA, while 125 (30%) had no significant degree of OSA. Of those with any degree of OSA, 127 (31% of total patients) were mild, 82 (20% of total patients) were moderate, 57 (14% of total patients) had severe OSA and 19 (5%) had OSA with potentially combined OHS. Average follow-up time post-pulse oximetry was 432.9 (241.9) days.

Male vs female groups

When comparing male with female patients, the male group was slightly older but of similar BMI, both groups had a similar sleep and mental health symptom score (ESS, HADS) and heart rate; there were about 3 times as many women as men in this cohort. There was no significant difference in length of hospital stay, with all but 2 patients admitted to a ward post-operatively; the 2 patients admitted to ICU were female. Men were on average heavier and had more severe sleep-disordered breathing, as indicated by the mean/minimum SpO₂, the ODI and the percentage of the night with an SpO₂ <90%, as well as the pulse rise index as an indicator of arousals; men were 20.3% more likely (85% of male patients compared to 64.7% of female patients) to require treatment recommendation like MAD, CPAP or referral for further respiratory assessment (Table 1).

	<u>Male</u>	<u>Female</u>	<u>p-value</u>
Age (years)	49.46 (12.1); n = 108	45.9 (11.7); n = 302	0.008
Weight (kg)	153.4 (29.0); n = 108	127.7 (23.6); n = 301	<0.001
BMI (kg x m⁻²)	49.35 (8.8); n = 108	47.6 (8.0); n = 302	0.055
Length of stay (days)	2.2 (1.3); n = 5	2.5 (1.1); n = 28	0.556
HADS (out of 42 points)	20.8 (6.6); n = 9	16.1 (7.3); n = 17	0.124
Mean heart rate (min⁻¹)	71.0 (10.1); n = 103	73.8 (9.4); n = 294	0.011

Pulse rise (h⁻¹)	39.8 (19.9); n = 104	32.2 (17.8); n = 297	<0.001
Mean SpO₂ (%)	93.3 (2.5); n = 106	94.4 (3.9); n = 303	0.004
Nadir SpO₂ (%)	73.4 (12.0); n = 104	76.8 (9.0); n = 297	0.002
4% ODI (h⁻¹)	22.8 (19.9); n = 106	12.8 (15.4); n = 303	<0.001
3% ODI (h⁻¹)	28.5 (21.6); n = 106	17.2 (17.8); n = 303	<0.001
<90% SpO₂ (% of sleep study)	14.4 (19.5); n = 106	5.8 (10.9); n = 303	<0.001

Table 1. Comparison of male and female cohort. BMI = body mass index; ODI = oxygen desaturation index; OSA = obstructive sleep apnoea.

Co-morbidities

Hypertension was present in 42% (n = 171) patients, 37% (n = 153) patients had diabetes mellitus, 25% (n = 104) had depression, 9% (n = 37) had asthma, 7% (n = 30) had high cholesterol/dyslipidaemia, 7% (n = 28) had polycystic ovarian syndrome (PCOS), 5% (n = 19) had impaired glucose tolerance, 5% (n = 19) had anxiety, 3% (n = 13) had chronic obstructive pulmonary disease (COPD), 2% (n = 9) had chronic kidney disease (CKD)/renal impairment, 2% (n = 8) had epilepsy or a history of seizures.

Medication

25% (n = 102) were taking one (or more) oral hyperglycaemic agent(s) (metformin, sitagliptin, gliclazide, liraglutide), 21% (n = 87) were taking a statin (simvastatin, atorvastatin, rosuvastatin), 17% (n = 69) were taking one (or more) antidepressant(s) (escitalopram/citalopram, fluoxetine/duloxetine/paroxetine/sertraline, amitriptyline), 17% (n = 68) were taking a proton-pump inhibitor (omeprazole, lansoprazole), 16% (n = 64) were taking a calcium channel blocker (amlodipine, nifedipine, diltiazem), 15% (n = 61) were taking an angiotensin-converting enzyme inhibitor ("ACEi"; ramipril, lisinopril, perindopril, enalapril), 14% (n = 59) were taking one (or more) inhaler(s) (salbutamol, salmeterol, seretide, ventolin, tiotropium, symbicort, clenil modulite, beclometasone, fluticasone), 9% (n = 37) were taking one (or more) injected insulin(s) (Humulin, Humalog, "insulin", Novomix, Novorapid), 9% (n = 37) were taking an angiotensin II receptor blocker ("ARB";

losartan, irbesartan), 6% (n = 25) were taking one (or more) anti-convulsants (gabapentin, pregabalin, carbamezipine, valproate), 6% (n = 25) were taking orlistat.

CPAP treatment

220 (54%) patients received no further treatment, 164 (40%) patients were prescribed CPAP treatment and 26 (6%) patients were recommended a mandibular advancement device for their symptoms. Patients who required CPAP therapy were, on average, older, heavier, with a higher BMI and more symptomatic than patients without, as via selection, they had a more severe degree of OSA (Table 2). Of those on CPAP (n = 164), 125 (76%) were prescribed CPAP pre- and post-operatively, 17 (10%) were prescribed post-operative extubation onto CPAP, and 22 (13%) were referred to the Lane Fox Unit for further respiratory assessment of non-invasive ventilation (NIV) vs CPAP; 2 of the patients referred for further assessment did not require CPAP. The patients with CPAP had an average pressure of 13.7 (2; n = 81) cmH₂O, an annual compliance of 64.0 (34.0; n = 50) %, and nightly use of 4.5 (1.9; n = 50) hours. The length of stay in hospital for the operated cohort was similar between CPAP and non-CPAP group.

	<u>CPAP</u>	<u>Non-CPAP</u>	<u>p-value</u>
Age (years)	49.5 (11.3); N = 155	44.9 (12.0); N = 241	<0.001
Male VS. Female ratio	0.63:1; N = 155	0.24:1; N = 244	<0.001
Weight (kg)	142.9 (29.8); N = 155	129.1 (24.5); N = 244	<0.001
BMI (kg.m⁻²)	50.3 (8.5); N = 155	46.6 (7.7); N = 244	<0.001
HADS (score out of 42)	16.1 (7.0); N = 10	20.5 (7.5); N = 14	0.153
Mean heart rate (min⁻¹)	75.8 (10.6); N = 152	71.4 (8.4); N = 239	<0.001
pulse rise (h⁻¹)	41.8 (20.7); N = 150	28.9 (15.0); N = 240	<0.001
Mean SpO₂ (%)	92.7 (3.8); N = 153	95.1 (3.2); N = 244	<0.001
Nadir SpO₂ (%)	69.0 (11.3) ; N = 150	80.4 (5.7) ; N = 240	<0.001
4% ODI (h⁻¹)	29.2 (19.7) ; N = 153	6.4 (6.5) ; N = 244	<0.001
3% ODI (h⁻¹)	36.4 (21.1) ; N = 153	9.5 (8.0); N = 244	<0.001
<90% SpO₂ (% of sleep study)	16.5 (17.8); N = 153	2.4 (6.8); N = 244	<0.001

Table 2. Comparison of patients with CPAP vs those without CPAP. LOS = length of stay; BMI = body mass index; ESS = Epworth Sleepiness Scale; HADS = Hospital Anxiety and Depression scale; ODI = oxygen desaturation index

Bariatric Surgery

During the follow up period (i.e. days since sleep study recording) of 719.4 (143; n = 53) days 53/413 (12.8%) patients had undergone bariatric surgery [80% female (44:9), age 48.5 (11.4) years, 138.0 (28.5) kg, 49.3 (8.2) kg/m²]. 48 patients were class III obese, including 20 patients who were “super obese”, and 5 patients were class I and II obese. 47% (n = 25) patients had hypertension, 30% (n = 16) had type 2 diabetes mellitus, 28% (n = 15) patients had depression, 11% (n = 6) had COPD, 9% (n = 5) had asthma. The patients had undergone either a laparoscopic sleeve gastrectomy (SG; n = 31), a Roux-en-Y gastric bypass (RYGB; n = 20), and in two patients the type of surgery was not documented, with or without a simultaneous hernia repair. There were no patient deaths in the operated population during the data collection period.

There were no significant differences between the surgical and non-surgical population with regards to demographics, symptom scores or nocturnal pulse oximetry data. CPAP treatment had been commenced in 47% (25:28) of this cohort, mean CPAP pressure was 13.1 (2.2) cmH₂O, nightly CPAP use was 4.2 (2.1) hours, and the ESS was 7.8 (5.0) points on treatment. The mean post-operative follow-up time was 375.3 (277.9) days. By then, patients had an average weight loss of 22.0% (10.5) of their body weight with no significant difference between the groups (Table 3). The average length of stay in hospital was 2.5 (1.2) days, there was no difference between patients on CPAP compared to those without (CPAP 2.6 (1.4) vs no CPAP 2.4 (1.0) days p=0.650).

Out of the 53 surgical patients, only 2 had any pre-, intra- or post-operative complications:

- A 63-year old female patient with COPD, not receiving CPAP, suffered from an acute kidney injury (AKI) post laparoscopic sleeve gastrectomy. This patient was treated on a non-ICU hospital ward for two days before being discharged; the patient has not had any relevant medical complications in the 9 months since their surgery.
- A 62-year old female patient with COPD, extubated onto CPAP, suffered from hypercapnic (type 2) respiratory failure (HCRF) post-laparoscopic sleeve gastrectomy. This patient was admitted to ICU, and was treated in ICU for two days before being discharged. This patient has not suffered any relevant medical complications in the 4 months since their surgery.

	<u>Surgical CPAP cohort</u>	<u>Surgical non-CPAP cohort</u>	<u>p-value</u>
<u>Weight (kg)</u>	139.5 (34.7); n = 25	136.7 (22.1); n = 28	0.718
<u>BMI (kg x m⁻²)</u>	49.7 (10.4); n = 25	49.1 (5.9); n = 28	0.794
<u>Weight loss (%)</u>	25.0 (10.5); n = 18	19.2 (9.8); n = 20	0.086

Table 1. Comparison of pre-operative weight, BMI and weight loss following surgery in patients on/off CPAP.

Discussion

OSA is the most common physical sleep disorder, form of sleep disordered breathing (SDB) and possibly also the most prevalent chronic respiratory disorder (8). OSA is compounded by the fact that the morbidly obese population breathe at a reduced functional residual capacity, approaching the residual volume, which reduces lung compliance, increases the physical work of breathing and minimizes the pressure gradient between the alveolar and intrapleural pressure (trans-pulmonary pressure) (8) necessary to drive minute ventilation for continuous gas exchange (6, 9). However, increased levels of neural respiratory drive in obesity decrease with the onset of sleep (8). In addition, basal metabolic rate and oxygen demand are increased, leading to a rapid decline in arterial oxygen saturation when breathing is interrupted (6). Increased intra-abdominal pressure creates intrinsic positive end-expiratory pressure, particularly in supine posture (8), and functions as a limit to the inspiratory load (6, 9, 16).

Summary

In a large cohort of bariatric surgery patients, sleep-disordered breathing is highly prevalent: 70% had some form of OSA, while 40% required peri-operative planning with CPAP therapy. Obese men had more severe OSA, while the majority of bariatric patients was female. Although only a minority of 13% had been operated during the follow up period, only one patient (2% of the surgical cohort), who had COPD and was extubated onto CPAP, suffered post-operative respiratory complications. None of the other patients had

any significant respiratory peri-operative complications. There was no significant difference in length of hospital stay between operated patients with CPAP compared to the non-CPAP cohort. Pre-operative established CPAP therapy and/or extubation onto CPAP proved to deliver the same outcomes as in the patient cohort with no or only mild OSA; CPAP therapy has proven to deliver an effective method of controlling respiratory complications during and after surgery.

Clinical significance

Previous studies have found similar results with regards to rates of OSA in bariatric surgery cohorts, between 73% and 78% (12, 13, 15) of bariatric surgery patients have some form of sleep-disordered breathing, with 24% suffering from moderate to severe OSA and 11% having findings suggestive of combined OSA/OHS (12).

Sleep-disordered breathing is a significant risk factor for perioperative complications: A systematic review identified 8 studies linking OSA to higher rates of hypercapnic respiratory failure (17). Patients with moderate to severe sleep-disordered breathing are at higher risk of mortality, sepsis and respiratory complications after elective coronary artery bypass-graft surgery (18). Patients with OSA and unidentified OHS had higher risks of postoperative respiratory failure, heart failure, prolonged intubation, and longer ICU and hospital length of stay than patients with nonhypercapnic OSA (19).

Obese patients with OSA present a challenge to anaesthetists, with a significantly higher risk of difficult mask ventilation and laryngoscopy (20), as well as requiring more intubation

attempts (21). Meta-analyses have established that patients with OSA are more than twice as likely to suffer peri-operative respiratory complications compared to patients without OSA (22, 23). Many other types of surgery carry an inherently increased risk of respiratory complications, even in patients with no prior risk factors (11). Screening for OSA may thus be applicable to these types of surgery as well as bariatric surgery.

Besides a difficult airway with high Mallampati score, COPD is one of the most commonly identifiable causes of post-operative pulmonary complications. OSA may be prevalent in 13.8% of COPD patients and significantly compounds peri-operative risk (24). Pre-operative screening for OSA (and treatment with CPAP if necessary) in pre-surgical COPD patients may be of clinical importance. However, 23% of patients with combined COPD and OSA may require bilevel positive airway pressure (BiPAP) for associated hypoventilation with hypercapnic respiratory failure (24). Hypercapnic (type 2) respiratory failure increases mortality (25), particularly in patients with COPD, even in those treated on a respiratory ITU (26). The COPD patient who suffered from a post-operative HCRF in our cohort may therefore have required non-invasive ventilation instead of CPAP and as such may not represent a lack of efficacy in peri-operative CPAP treatment.

CPAP is a routine and beneficial treatment for moderate to severe OSA (27) and has been recorded as an effective method of reducing peri-operative respiratory complications compared to patients with undiagnosed OSA without receiving CPAP (11, 28). Although

CPAP does reduce symptoms relating to apnoea, such as abnormalities in night-time oxygen levels and excessive daytime sleepiness, it has also positive effects on memory and cognition (29, 30), improves quality of life, reduces blood pressure (31) and improves cardiac outcomes (32). However, despite patients experiencing relief of sleep-related symptoms, compliance to CPAP treatment remains suboptimal, with as many as half of the patients not sufficiently adhering to treatment at one year (17). Indeed, our study found that patients only used their prescribed CPAP during two out of every three nights, on average.

The similar length of stay between the groups with and without OSA highlights the effectiveness of CPAP – patients prescribed appropriate CPAP had outcomes and hospital stays comparable to patients who did not require it at all. This demonstrates that CPAP is effective in managing the respiratory needs of bariatric patients and those with obstructive sleep apnoea.

The Epworth Sleepiness Scale (ESS) is the most commonly used questionnaire in sleep medicine (13), but it does not differentiate between various causes of excessive daytime sleepiness (EDS) (33), or correlate with objective measures of EDS (9) and its applicability to obese patients is controversial (34). For these reasons, the STOP-BANG questionnaire has taken precedence for OSA screening in obese patients in the pre-operative clinics (20). The STOP-BANG questionnaire is based on snoring, daytime tiredness, observed apnoeic episodes, BMI over 35 kg/m², advanced age, male gender, a history of hypertension and neck circumference (35). These criteria are highly sensitive (94-96%) in the diagnosis of moderate-severe OSA (36).

Limitations

Patients studied were selected solely based on high-risk STOP-BANG scores, thus patients with lower scores were not followed. Future research should attempt to include all surgical patients to determine the presence (or absence) of any peri-operative respiratory complications in those not screened via the sleep service. Additionally, although highly sensitive, the STOP-BANG score is not a measure of OSA, and patients with actual OSA may not have a high STOP-BANG score, excluding them from the cohort despite their suitability for treatment.

Furthermore, all patients with moderate-severe OSA were treated with CPAP, and we cannot claim that there was an increased risk of complications if these patients had remained untreated. However, the fact that overall risks were low and comparable between groups is reassuring in that the proposed management plan is sufficient. In the context of a randomised controlled clinical trial, the use of sham-CPAP, an effective placebo for CPAP (37), if ethically acceptable, would provide more evidence about the effectiveness of peri-operative CPAP. Hip circumference measurements would have been of interest for assessing insulin resistance. HAD scores for surgical patients would have also been useful to assess the psychological profile of this cohort. However, the surgical cohort matched the non-surgery cohort, and it is therefore likely that the HAD scores could be assumed to be similar. Additionally, although CPAP is effective in OSA, BiPAP may be more suitable for patients with combined OSA and COPD.

Lastly, this study focused on peri-operative outcomes in bariatric/abdominal surgery, but pre-operative OSA screening and subsequent CPAP treatment may be applicable to other forms of (respiratory) high-risk surgery as well.

Conclusion

Bariatric patients screened pre-operatively for OSA and treated with CPAP, according to guidelines, suffer few respiratory complications. Pre-operative screening for OSA and peri-operative treatment with CPAP in morbidly obese patients is an effective method of reducing respiratory disease-related morbidity and mortality in the bariatric population.

Acknowledgements

Dr. Steier's contribution to this project was supported by the National Institute for Health Research (NIHR) Biomedical Research Centre based at Guy's and St Thomas' NHS Foundation Trust and King's College London, who part funded his salary. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.

References

1. McPherson K, Marsh T, Brown M (2013), *Tackling obesities: future choices—modelling future trends in obesity and the impact on health*. 2nd Edition. Foresight, 2007.
2. Health and Social Care Information Centre. (2013) *Statistics on Obesity, Physical Activity and Diet: England, 2013*. Leeds: Health and Social Care Information Centre.
3. Zammit C, Liddicoat H, Moonsie I et al. (2010), *Obesity and respiratory diseases*, International Journal of General Medicine; 3: pp. 335-43.
4. Mutter TC, Chateau D, Moffatt M, et al. (2014), *A matched cohort study of post-operative outcomes in obstructive sleep apnea*, Anesthesiology; 121: pp. 707–18
5. Steier J, Martin A, Harris J, Jarrold I, Pugh D, Williams A (2013), *Predicted relative prevalence estimates for obstructive sleep apnoea and the associated healthcare provision across the UK*, BMJ Thorax; 69(4)

6. Nightingale CE, (2015), *Peri-operative management of the obese surgical patient 2015*, Anaesthesia 2015; 70: pp. 859-876
7. Pengo MF, Drakatos P, Kosky C et al. (Jun 2014), *Nocturnal pulse rate and symptomatic response in patients with obstructive sleep apnoea treated with continuous positive airway pressure for one year*, Journal of Thoracic Disease; 6(6): pp. 598-605
8. Steier J, Jolley CJ, Seymour J, et al. (2009), *Neural respiratory drive in obesity*, Thorax 2009; 64: pp. 719-725.
9. Steier J, Kent B, (2016) *Assessment and treatment of sleep-disordered breathing in the morbidly obese surgical patient*, Cambridge University Press, September 2016
10. Smetana GW (March 1999), *Preoperative pulmonary evaluation*, New England Journal of Medicine; 340(12); pp. 937-44
11. Qaseem A et al. (May 2006), *Risk Assessment for and Strategies To Reduce Perioperative Pulmonary Complications for Patients Undergoing Noncardiothoracic Surgery: A Guideline from the American College of Physicians*, Annals of Internal Medicine; 144: pp. 575-580. doi: 10.7326/0003-4819-144-8-200604180-00008;
12. Reed K, Pengo MF, Steier J (February 2016), *Screening for sleep-disordered breathing in a bariatric population*, Journal of Thoracic Disease 8(2): pp. 268–275.
13. Johns MW (1991), *A new method for measuring daytime sleepiness: the Epworth sleepiness scale*, Sleep; 14 (6): pp. 540–5.
14. Bjelland I et al. (2002), *The validity of the Hospital Anxiety and Depression Scale: an updated literature review*, Journal of Psychosomatic Research; 52(2): pp. 69–77.

15. Lopez PP, Stefan B, Schulman CI et al. (2008), *Prevalence of sleep apnea in morbidly obese patients who presented for weight loss surgery evaluation: more evidence for routine screening for obstructive sleep apnea before weight loss surgery*, The American Surgeon; 74: pp. 834-8.
16. Steier J, Jolley CJ, Seymour J, et al. (15 April 2010) *Increased load on the respiratory muscles in obstructive sleep apnea*, Respiratory Physiology & Neurobiology; 171(1): pp. 54-60. doi: 10.1016/j.resp.2010.01.012. published online 29 January 2010
17. Opperer M, Cozowicz C, Bugada D (2016), *Does Obstructive Sleep Apnea Influence Perioperative Outcome? A Qualitative Systematic Review for the Society of Anesthesia and Sleep Medicine Task Force on Preoperative Preparation of Patients with Sleep-Disordered Breathing*, Anesthetics and Analgesia; 122(5): pp. 1321-34.
18. Rupprecht S, Schultze T, Nachtmann A (2017), *Impact of sleep disordered breathing on short-term post-operative outcome after elective coronary artery bypass graft surgery: a prospective observational study*, European Respiratory Journal, 49 (4): 1601486
19. Chung F, Nagappa M, Singh M, Mokhlesi B, (February 2016), *Contemporary Reviews in Sleep Medicine CPAP in the Perioperative Setting: Evidence of Support*, Chest, 149 (2): pp. 586–597
20. Kheterpal S, Healy D, Aziz MF et al. (2013), *Incidence, predictors, and outcome of difficult mask ventilation combined with difficult laryngoscopy: a report from the multicenter perioperative outcomes group*, Anesthesiology; 119(6): pp. 1360-1369.

21. Stierer TL, Wright C, George A et al. (2010), *Risk assessment of obstructive sleep apnea in a population of patients undergoing ambulatory surgery*, Journal of Clinical Sleep Medicine; 6(5): pp. 467-472.
22. Kaw R, Chung F, Pasupuleti V et al. (2012), *Meta-analysis of the association between obstructive sleep apnoea and postoperative outcome*, British Journal of Anaesthesia; 109(6): pp. 897-906.
23. Hai F, Porhomayon J, Vermont L (2014), *Postoperative complications in patients with obstructive sleep apnea: a meta-analysis*, Journal of Clinical Anesthesia; 26(8): pp. 591-600.
24. Kuklisovaa Z, Tkacova R, Joppa P, Wouters E, Sastry M, *Severity of nocturnal hypoxia and daytime hypercapnia predicts CPAP failure in patients with COPD and obstructive sleep apnea overlap syndrome*, Sleep Medicine; 30: pp. 139–145
25. Hukins C et al. (February 2017), *Management of Hypoxaemic Respiratory Failure in a Respiratory High Dependency Unit*, Internal Medicine Journal, accepted author manuscript; doi:10.1111/imj.13403
26. Khilnani GC, Banga A, Sharma SK (2004), *Predictors of mortality of patients with acute respiratory failure secondary to chronic obstructive pulmonary disease admitted to an intensive care unit: a one year study*, Biomed Central Pulmonary Medicine; 4(12)
27. Giles TL et al (2006), *Continuous positive airways pressure for obstructive sleep apnoea in adults*, Cochrane Database Systematic Review; (1): CD001106

28. Gami AS, Howard DE, Olson EJ et al. (2005), *Day-night pattern of sudden death in obstructive sleep apnea*, New England Journal of Medicine; 352: pp. 1206-14.
29. Ferini-Strambi L, Baietto C, Di Gioia MR, et al (2003). *Cognitive dysfunction in patients with obstructive sleep apnea (OSA): partial reversibility after continuous positive airway pressure (CPAP)*, Brain Research Bulletin; 61: pp. 87-92.
30. Dalmases M et al. (November 2015), *Effect of CPAP on Cognition, Brain Function, and Structure Among Elderly Patients With OSA: A Randomized Pilot Study*, Chest; 148(5): pp. 1214-23
31. McNicholas WT, Bonsignore MR (2007), *Management Committee of ECAB. Sleep apnoea as an independent risk factor for cardiovascular disease: current evidence, basic mechanisms and research priorities*, European Respiratory Journal; 29(1): pp. 156-178.
32. Doherty LS, Kiely JL, Swan V et al. (2005), *Long-term effects of nasal continuous positive airway pressure therapy on cardiovascular outcomes in sleep apnea syndrome*, Chest; 127: pp. 2076-84.
33. Slater G, Steier J (2012), *Excessive daytime sleepiness in sleep disorders*, Journal of Thoracic Disease, 2012; 4(6): pp. 608-616.
34. Slater G, Pengo MF, Kosky C, Steier J (2013), *Obesity as an independent predictor of subjective excessive daytime sleepiness*. Respiratory Medicine; 107(2): pp. 306-309.
35. Chung F, Yegneswaran B, Liao P et al (2008), *STOP questionnaire: a tool to screen patients for obstructive sleep apnea*, Anesthesiology; 108(5): pp. 812-821.

36. Nagappa M, Liao P, Wong J, et al. (2015), *Validation of the STOP-Bang Questionnaire as a Screening Tool for Obstructive Sleep Apnea among Different Populations: A Systematic Review and Meta-Analysis*, PloS one; 10(12): e0143697.
37. Rodway GW et al. (February 2010), *Evaluation of sham-CPAP as a placebo in CPAP intervention studies*, Sleep; 33(2): pp. 260-6.

Appendices

1. O'Keeffe T, Patterson EJ (2004), *Evidence supporting routine polysomnography before bariatric surgery*, Obesity Surgery; 14: pp. 23-6.
2. Chai-Coetzer CL, Luo YM, Antic NA et al. (2013), *Predictors of long-term adherence to continuous positive airway pressure therapy in patients with obstructive sleep apnea and cardiovascular disease in the SAVE study*, Sleep; 36(12): pp. 1929-1937.